

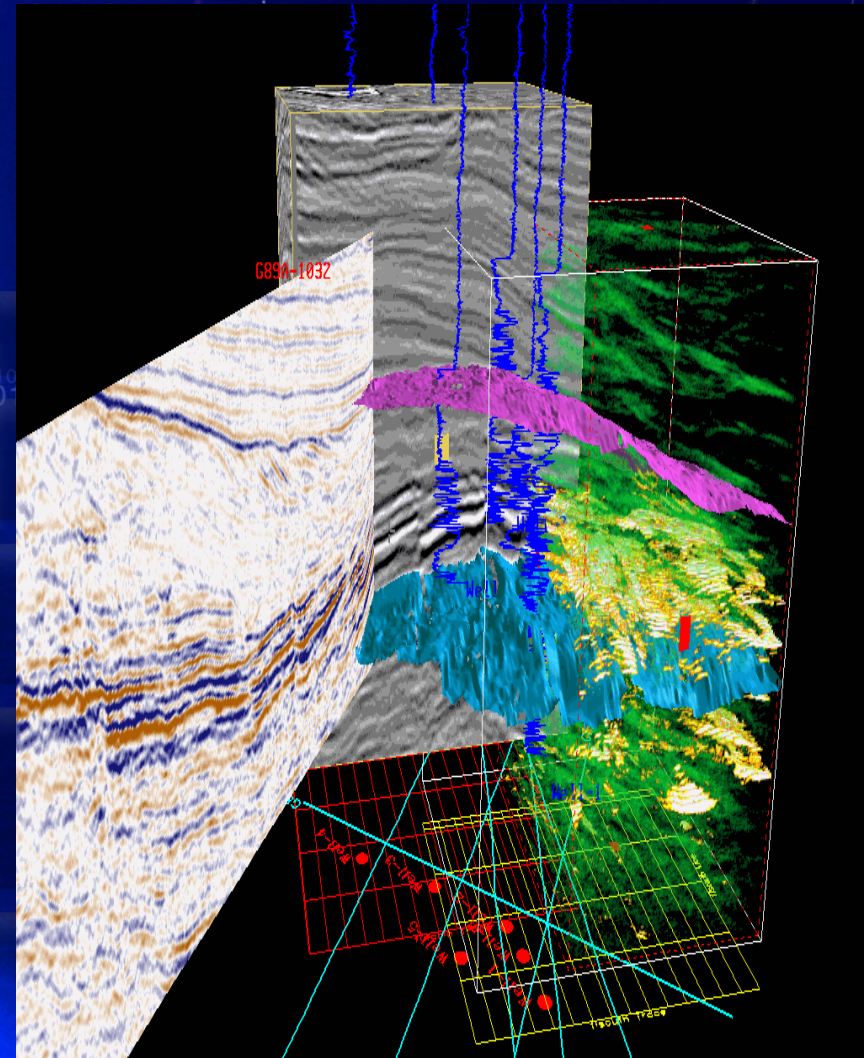
Reservoir Services

Services and Solutions

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Reservoir Services Review

- **Reservoir Services**
 - Objectives
 - Q-Reservoir Workflow
- **RS Operations**
 - Interpretation
 - Attributes
 - Inversion
 - Seismic classification
 - 4D



Reservoir Services - ECA / EUR history

- **RS, EUR formed in May, 2003**
 - **Integration with Data Consulting Services**
 - **Focus on Q Projects**
 - **Running 3'd party projects**

Role of Reservoir Services

To lead shift toward reservoir solutions

Reservoir Services use processed seismic datasets to produce reservoir description volumes such as;

Porosity

Water Saturation - the % mix of water & hydrocarbons

Relative Acoustic Impedance

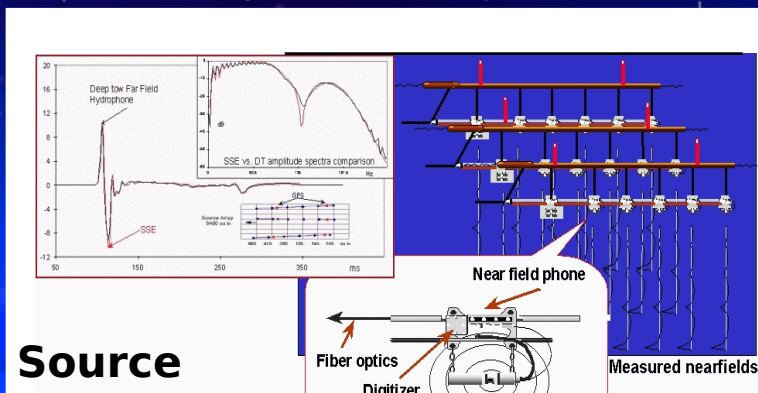
Primary Impedance

Shear Impedance

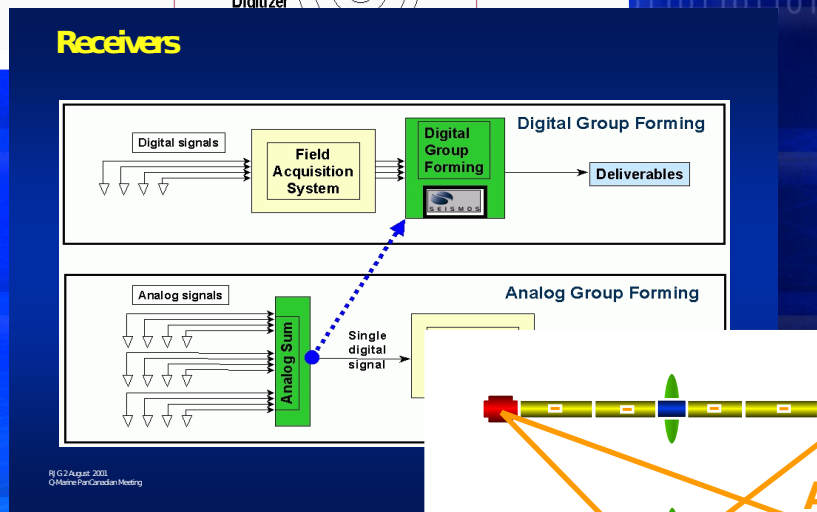
Time Lapse difference (4D)

Marine system components

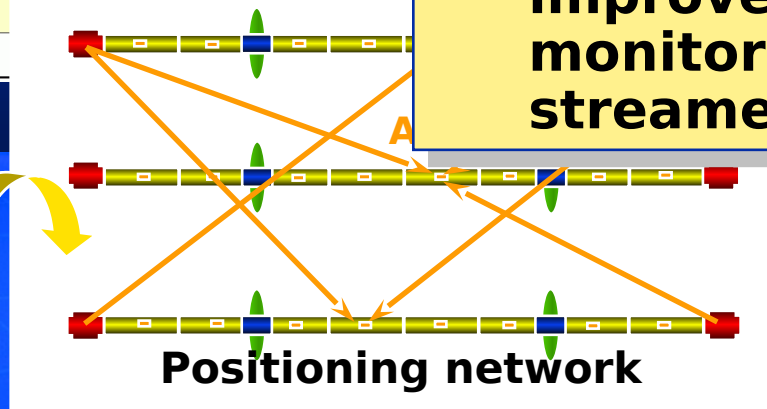
- Less noise of all types
- Better signal fidelity
- High density single sensor sampling
- Steerable streamers significantly improve repeatability
- Higher fidelity recording detects pressure
- Rapid 4D differencing due to compatibility of improved source monitoring and streamer positioning



Source



Receivers

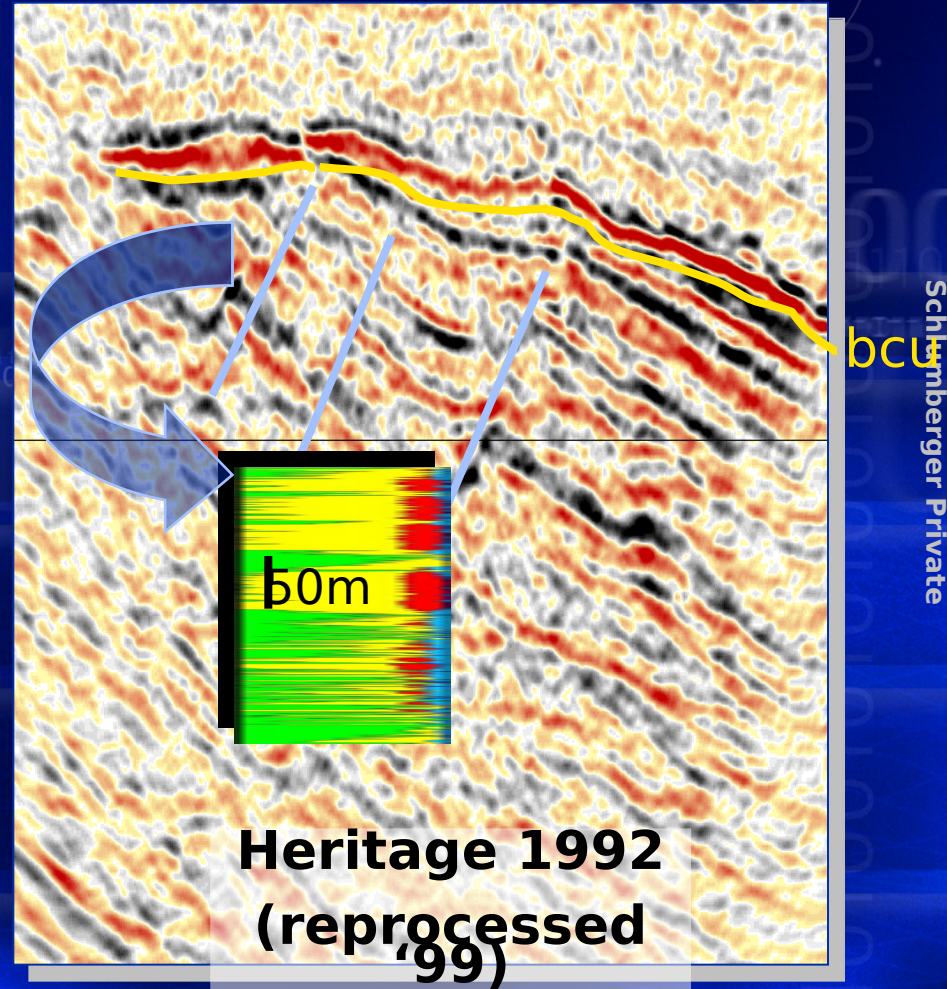


Positioning network



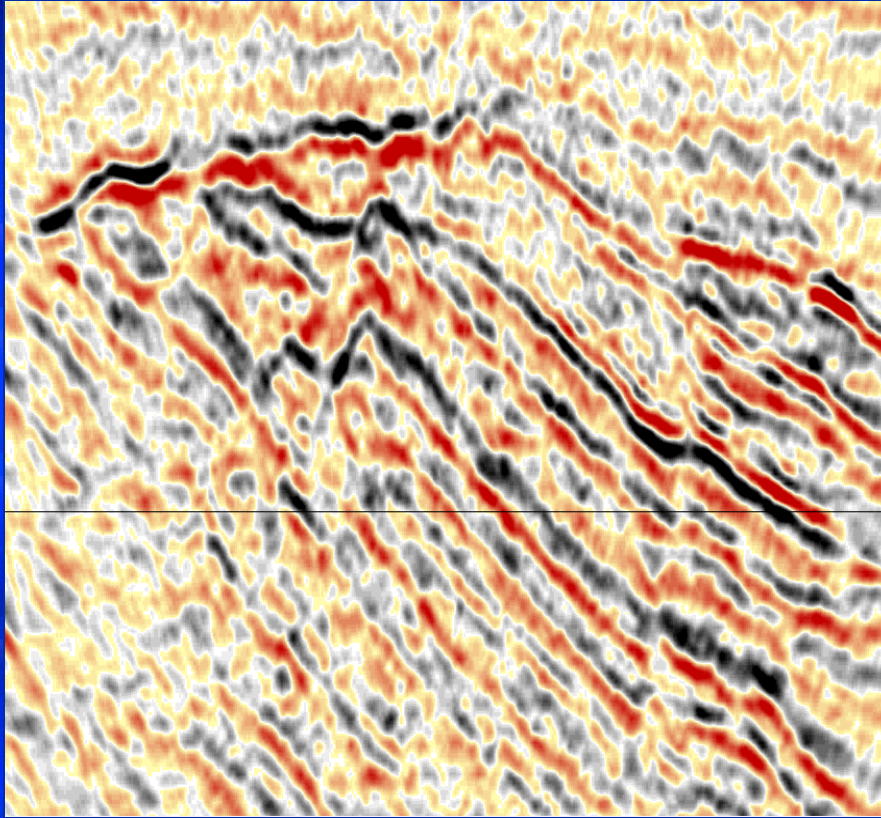
Reservoir Seismic for Enhanced Oil Recovery Project

- Reservoir Services will interpret (identify rock types & structure) all Q Surveys
- EOR schemes planned to optimize late production
- Requires improved seismic data
 - Fault resolution and flow barrier definition
 - Resolution of unmapped fault blocks
 - Highly repeatable seismic for forward looking baseline

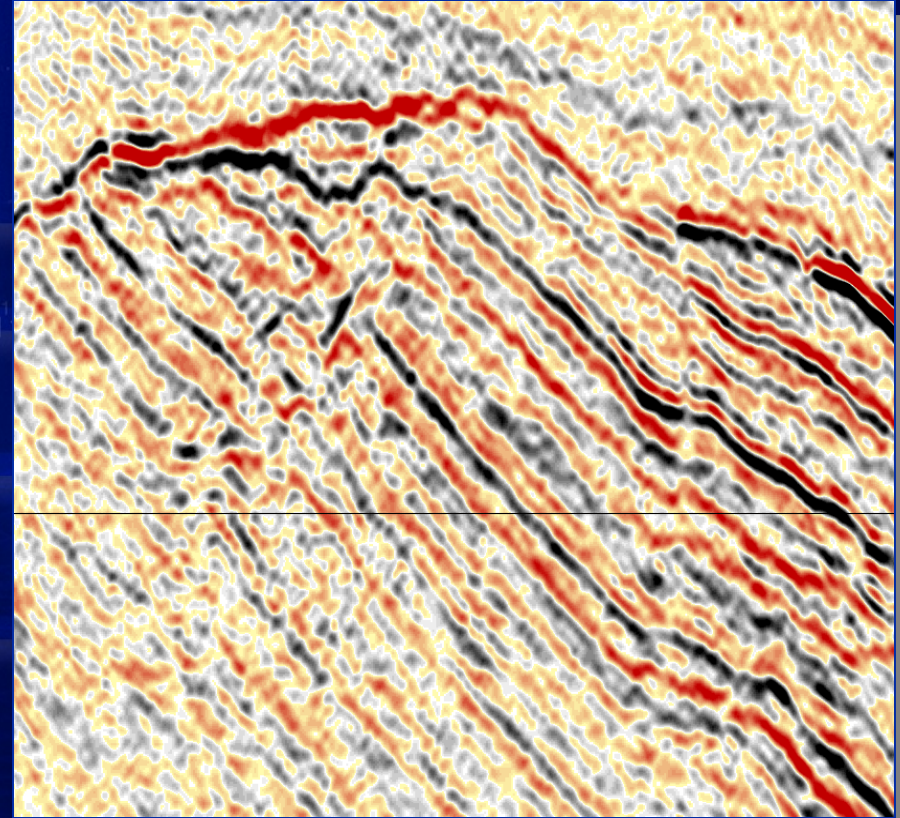


Courtesy BP

Magnus seismic data comparison

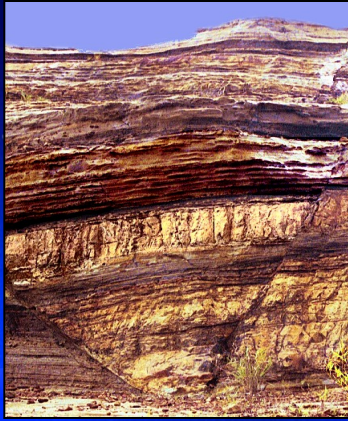


Heritage 1992 (repro 1999)



2001 survey

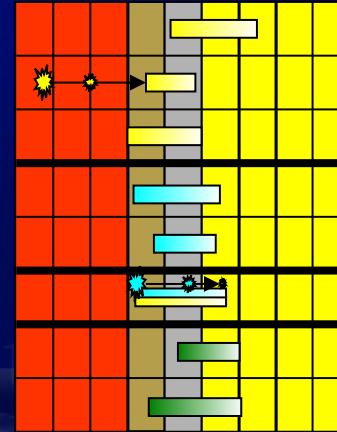
Q-reservoir - Schematic workflow



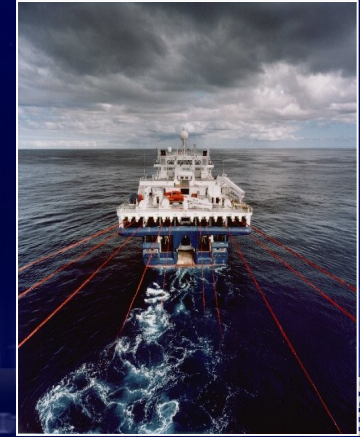
- Understand reservoir, geological & economic issues



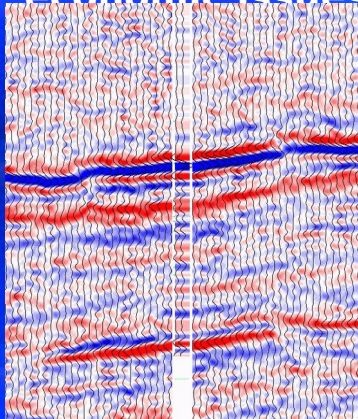
- Build integrated well and seismic database



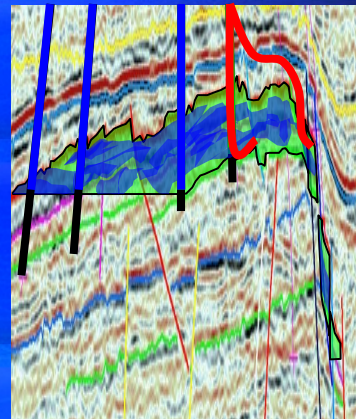
- Survey evaluation and design



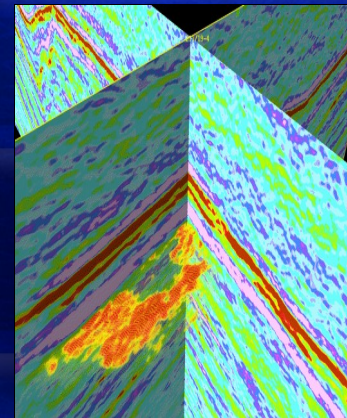
- Seismic acquisition



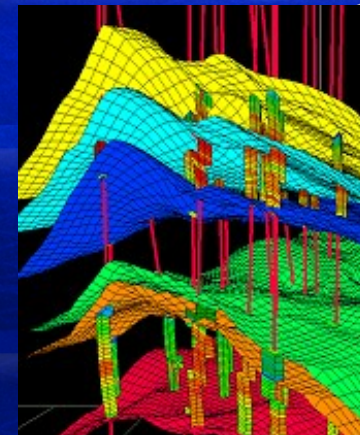
- Well-driven seismic processing



- Interpretation & reservoir delineation

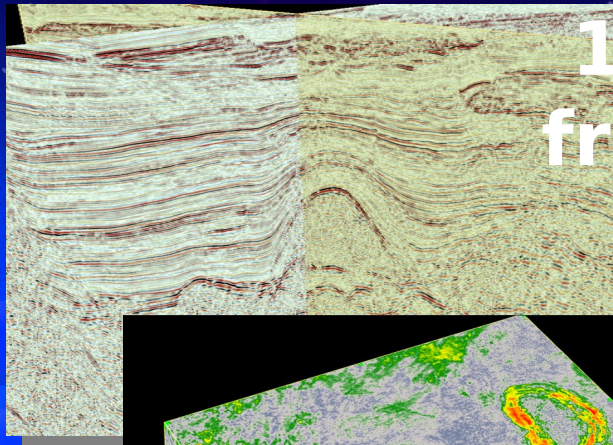


- Attribute analysis, AVO & inversion

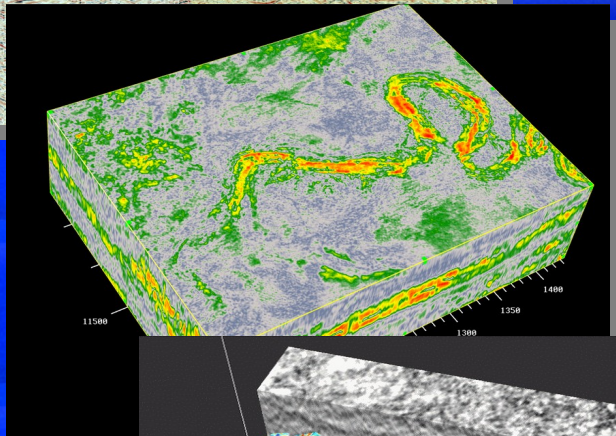


- Seismic-driven geo-cellular modeling

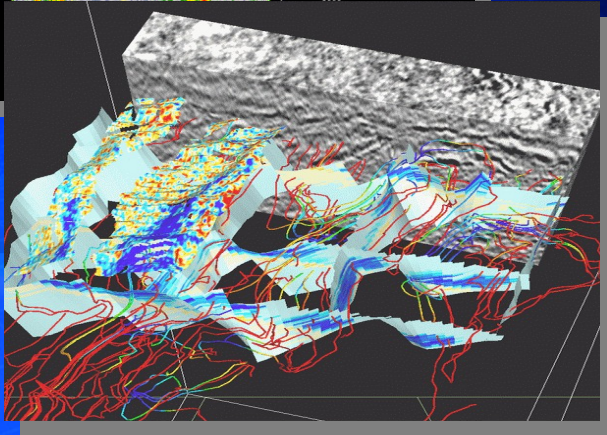
Three stages in seismic reservoir management



1. Defining the geometric framework of the reservoir 'Interpretation'

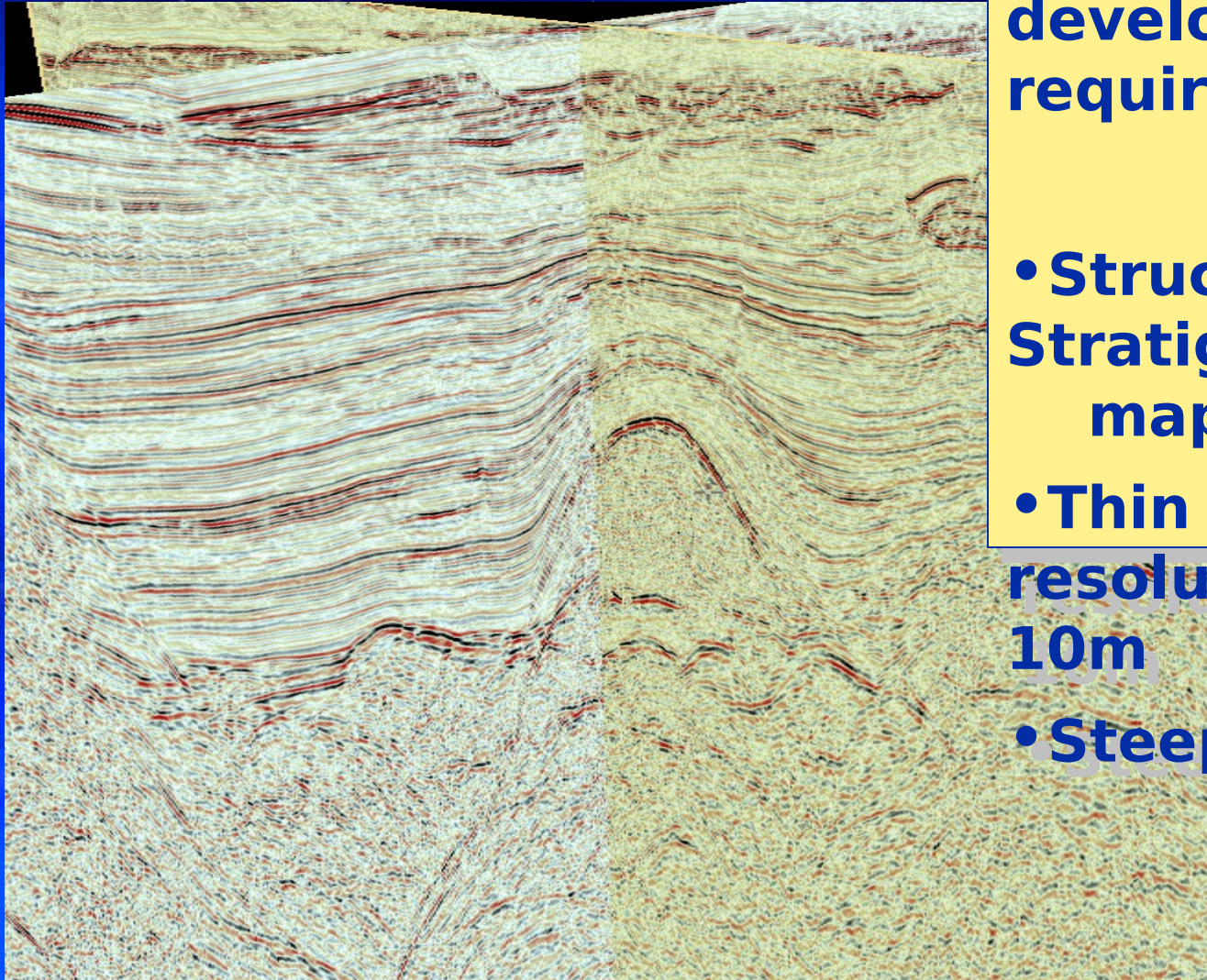


2. Qualitative & quantitative description of rock & fluid properties



3. Flow surveillance -monitoring of reservoir saturation & pressure

1. Defining the geometric framework of the reservoir



Reservoir development requirements:

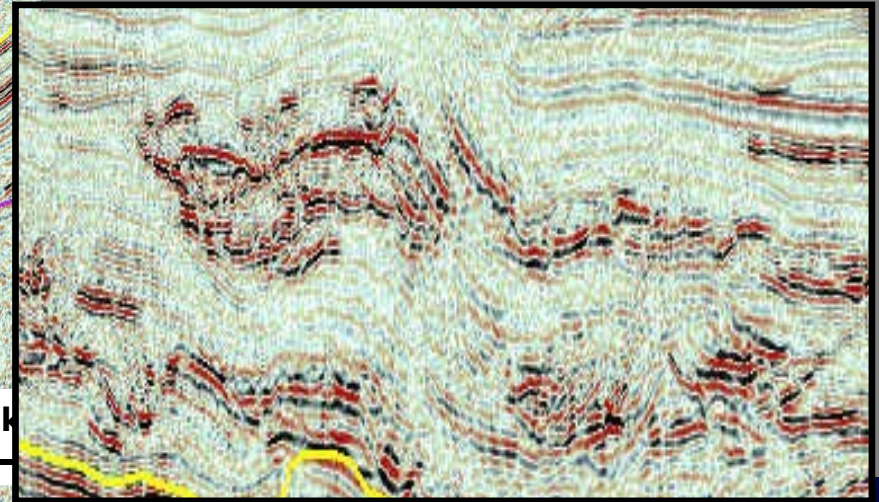
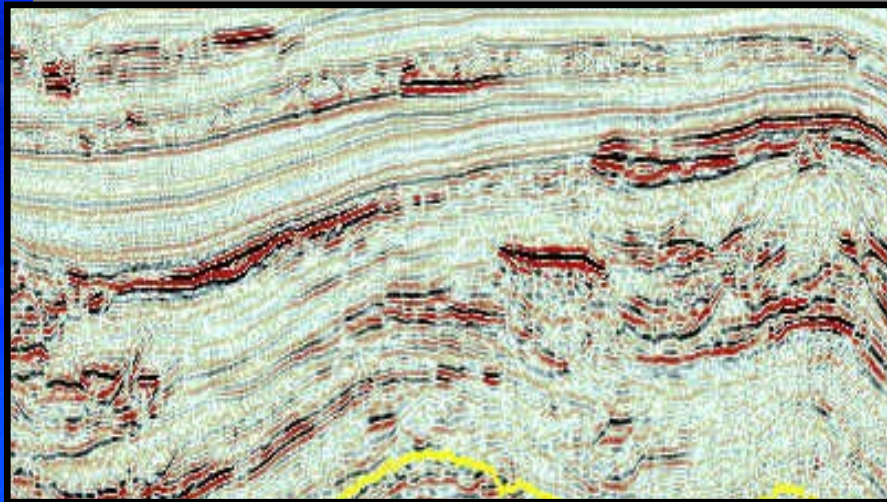
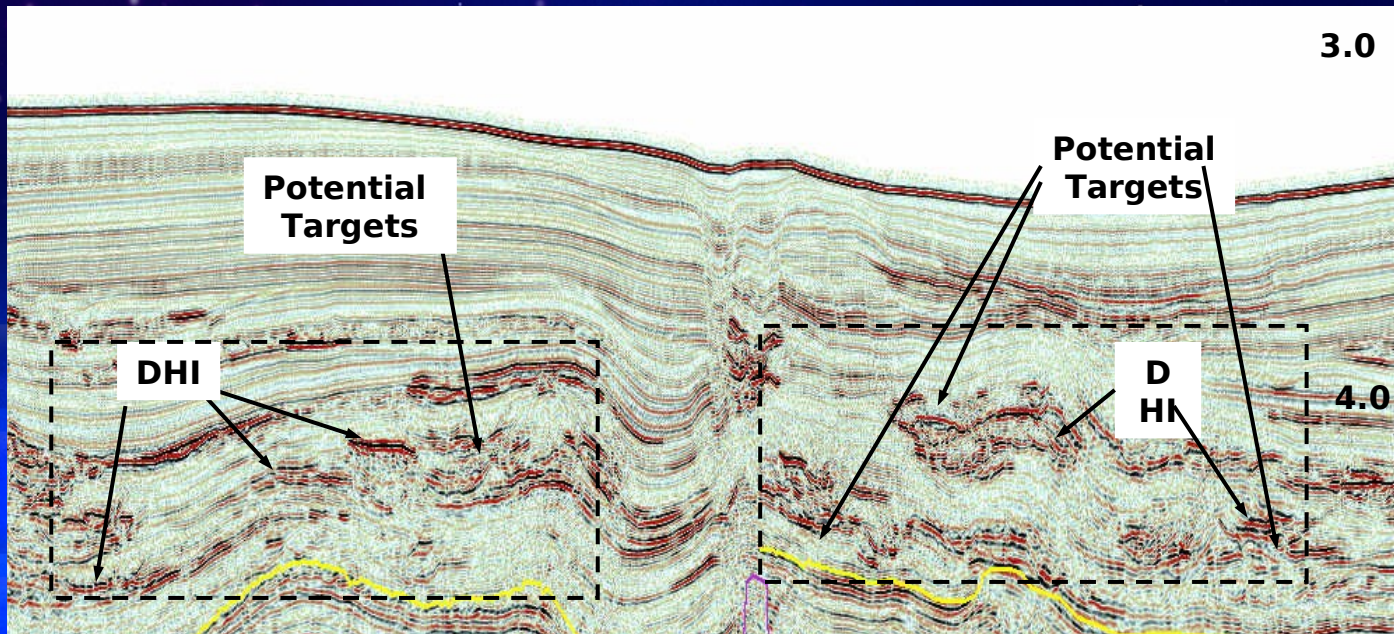
- **Structural and Stratigraphic mapping**

- **Thin bed**

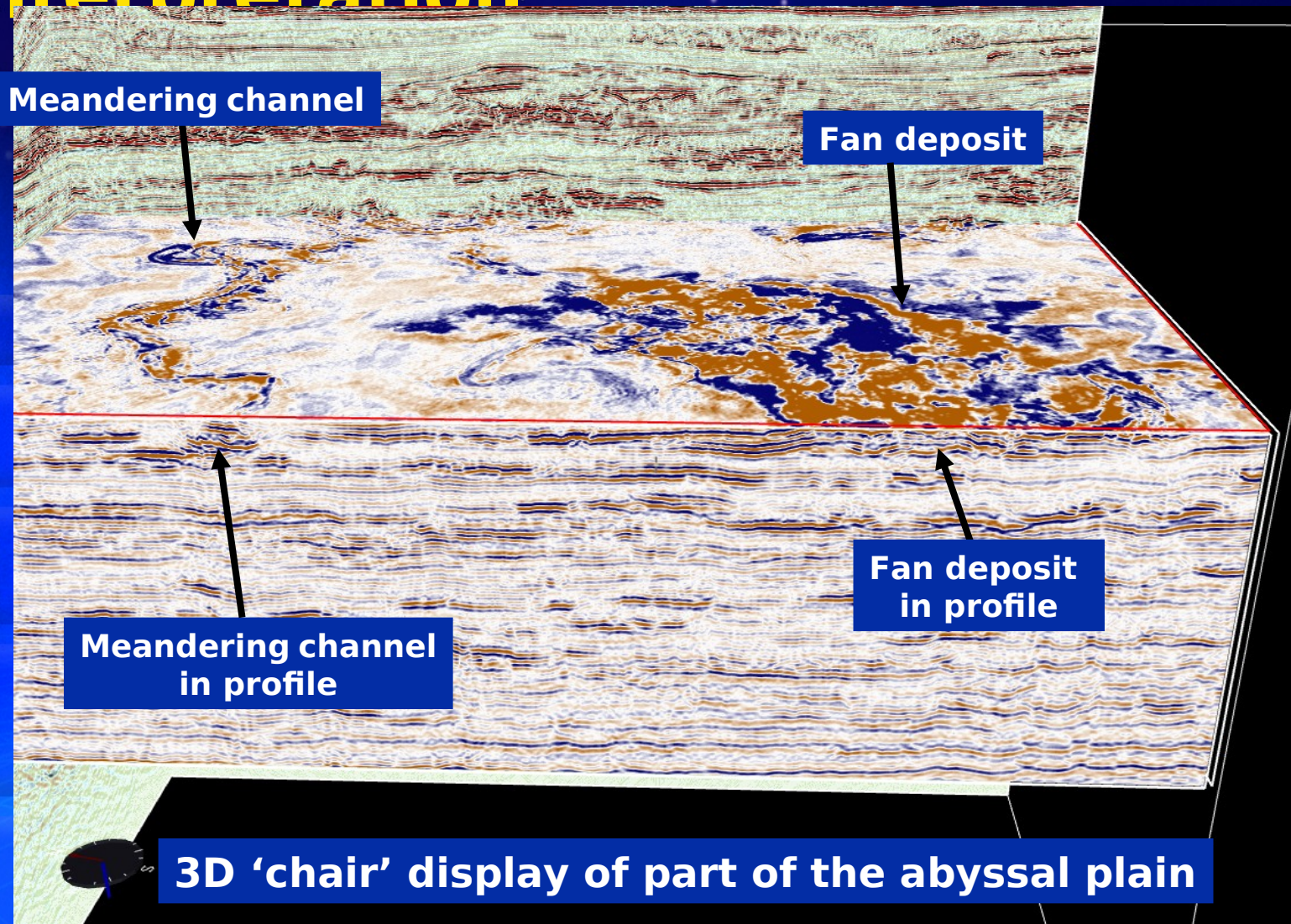
resolution - 5 to 10m

- **Steep dip imaging**

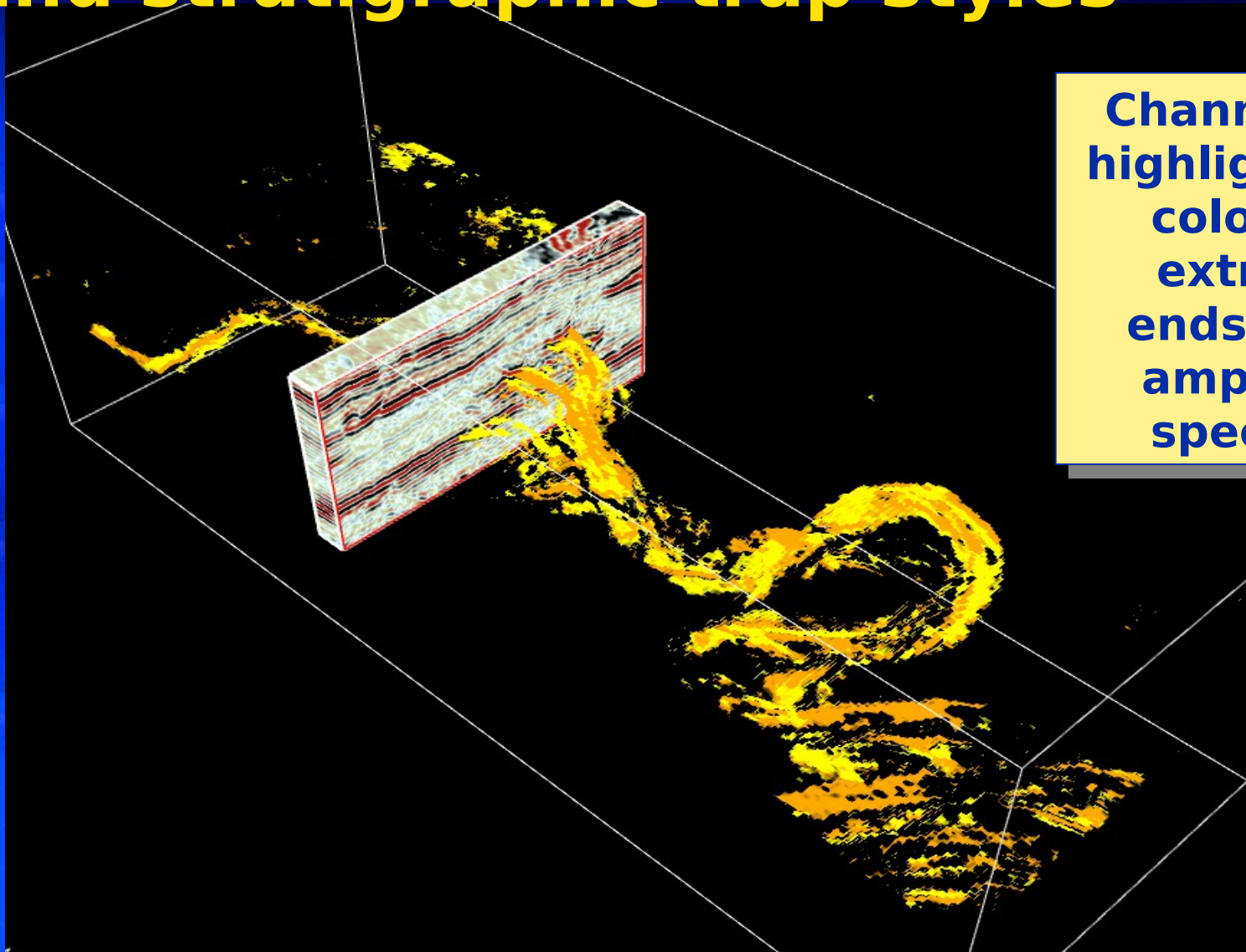
Angola Prospectivity from Seismic



Seismic Interpretation



High resolution seismic data enables the definition of sedimentary features and stratigraphic trap styles

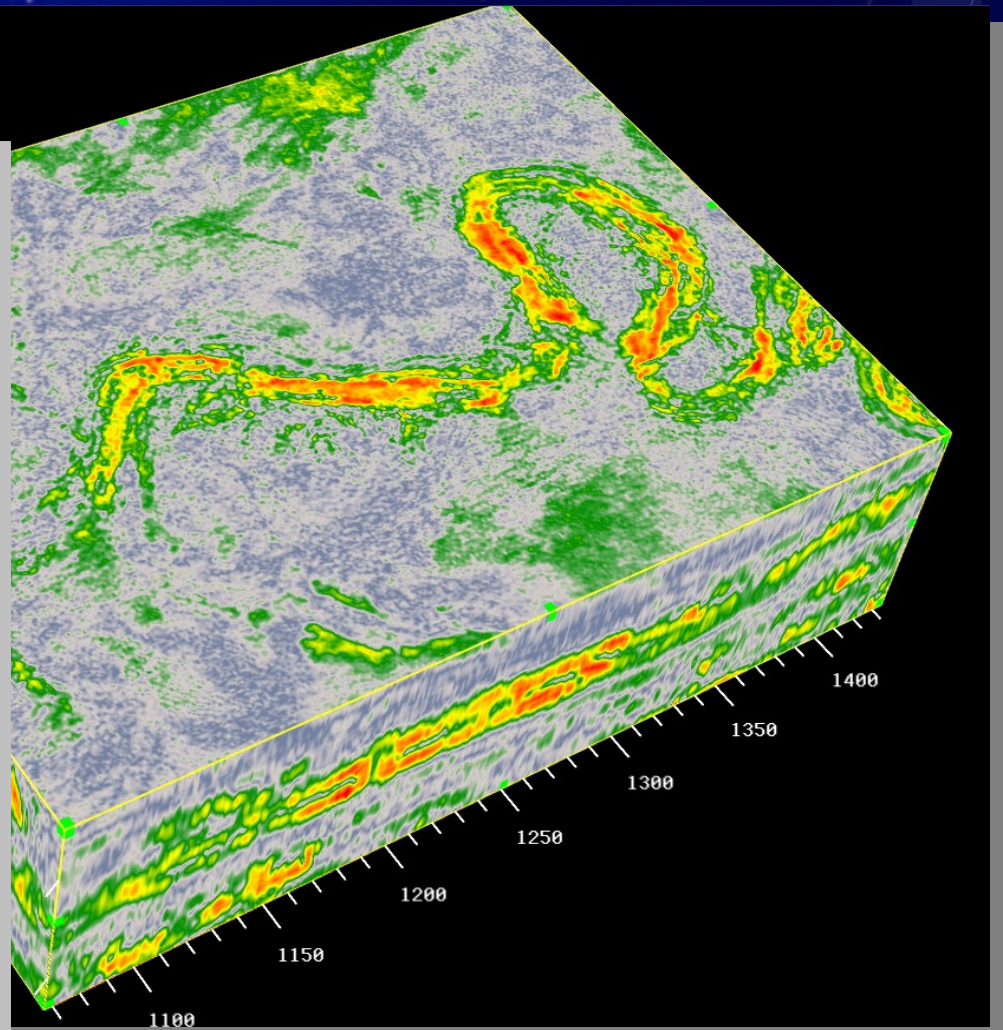


Channels are highlighted by colouring extreme ends of the amplitude spectrum

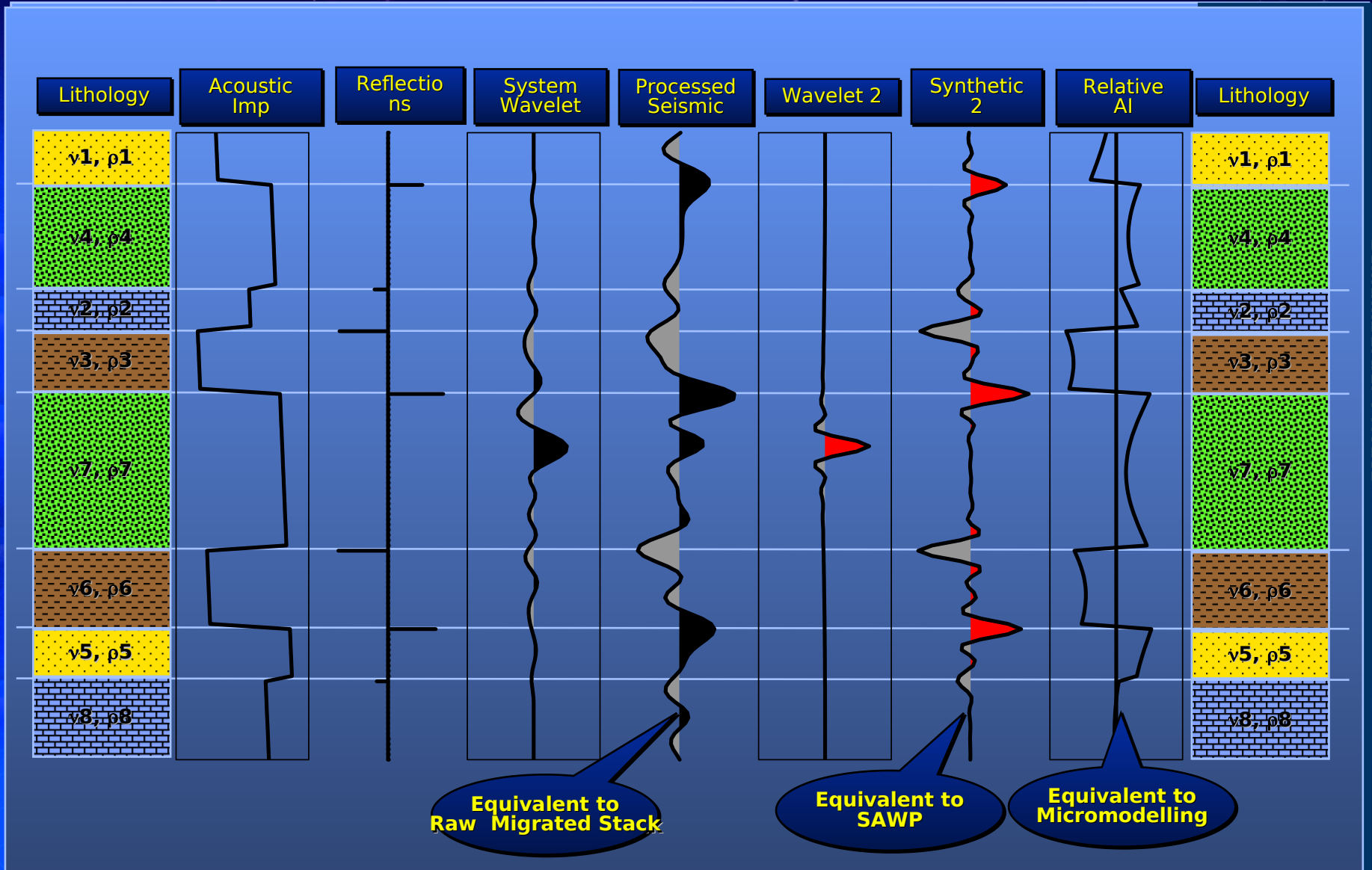
2. Qualitative & quantitative definition of rock & fluid properties

Reservoir development requirements:

- **Lithology / fluid prediction**
- **Porosity mapping**
- **Fracture networks and permeability**
- **Saturation / pressure mapping**



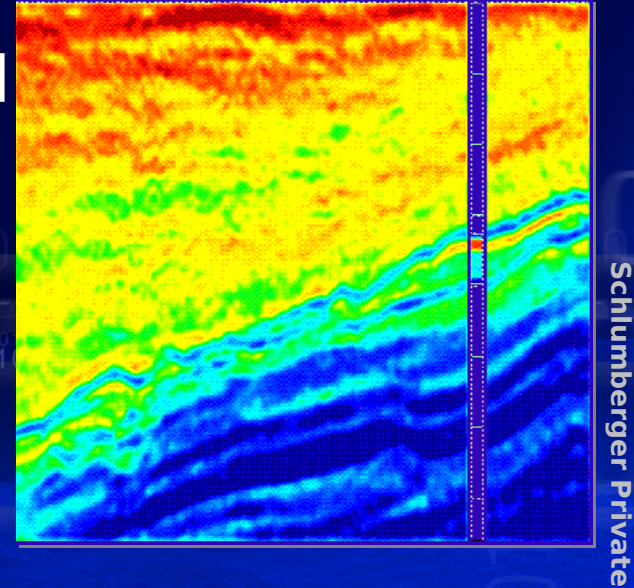
Seismic inversion to impedance



Definitions

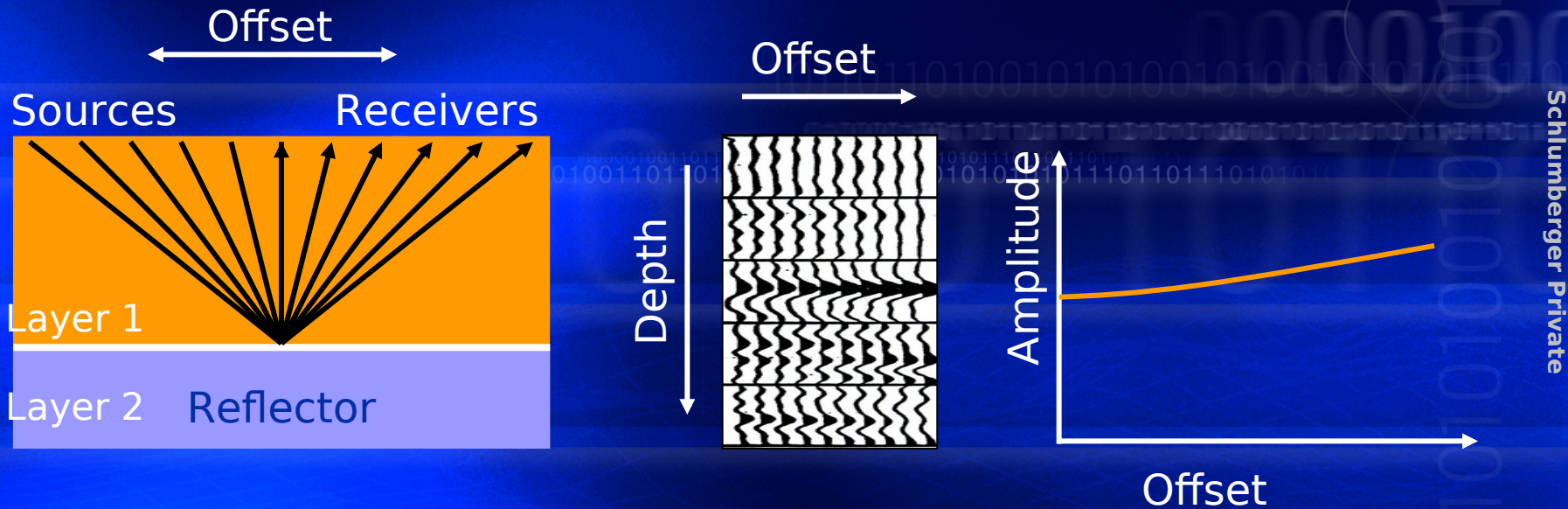
Seismic Acoustic Inversion

- Transformation of a band limited reflection sequence into meaningful petro-acoustic information



- Post stack
 - Simple P-wave inversion
- Pre-stack
 - Includes velocity and shear wave information

Introduction: Basic AVO Concepts

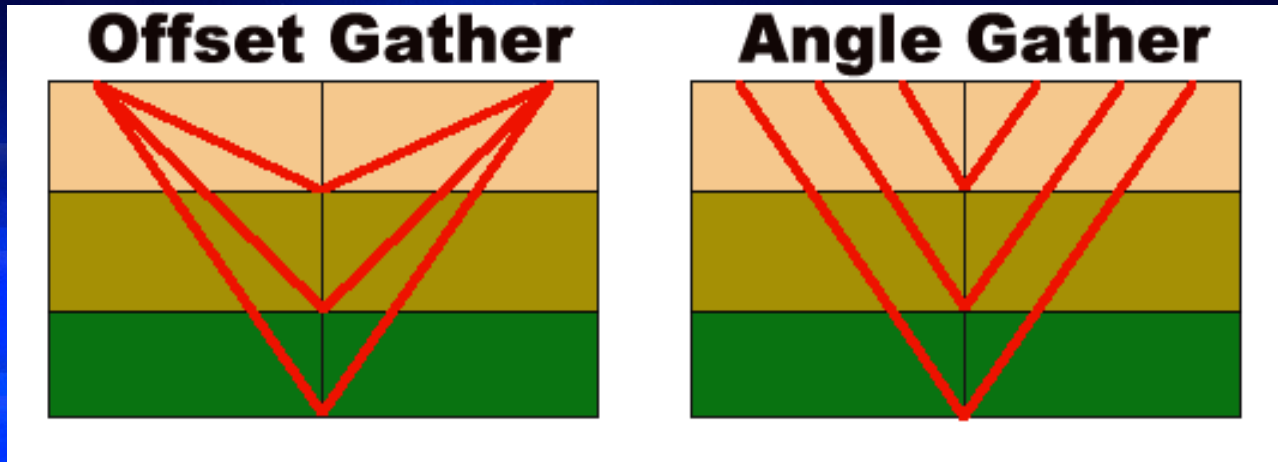


Obtain Elastic Parameters from AVO

What can we expect from AVO?

- AVO response changes with lithology, porosity and fluid content.
- Expect to distinguish fluids in a reservoir layer where lithology and porosity don't change
- Expect to distinguish lithology and porosity changes for layers with known fluid
- Well data needed to calibrate the AVO data

Rather than AVO we Should say AVA



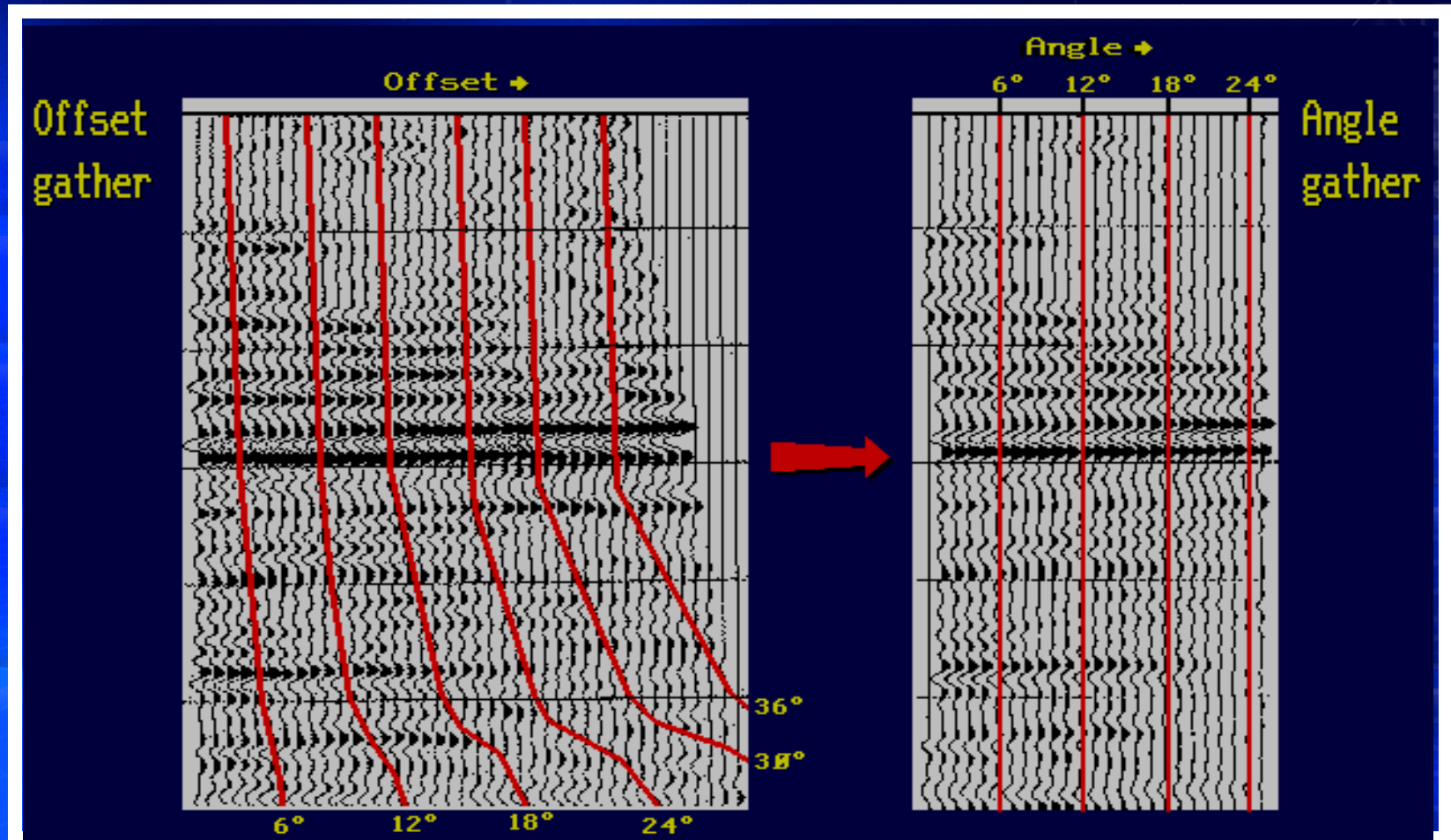
Note:

Angle of incidence decreases with depth for constant offset trace

Angle of incidence constant for all depths on a constant angle trace

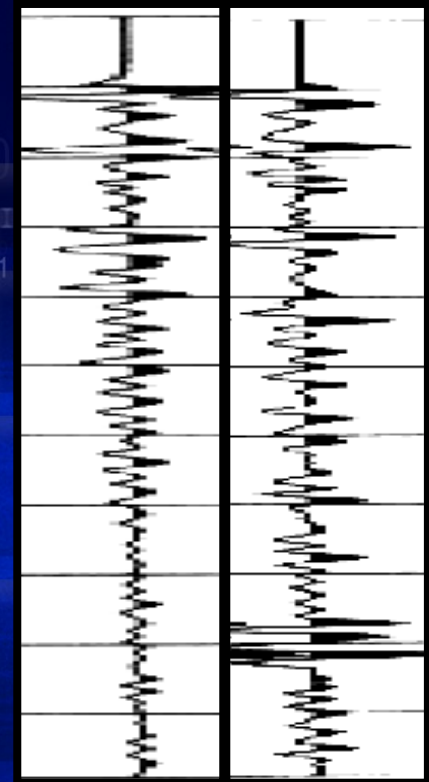
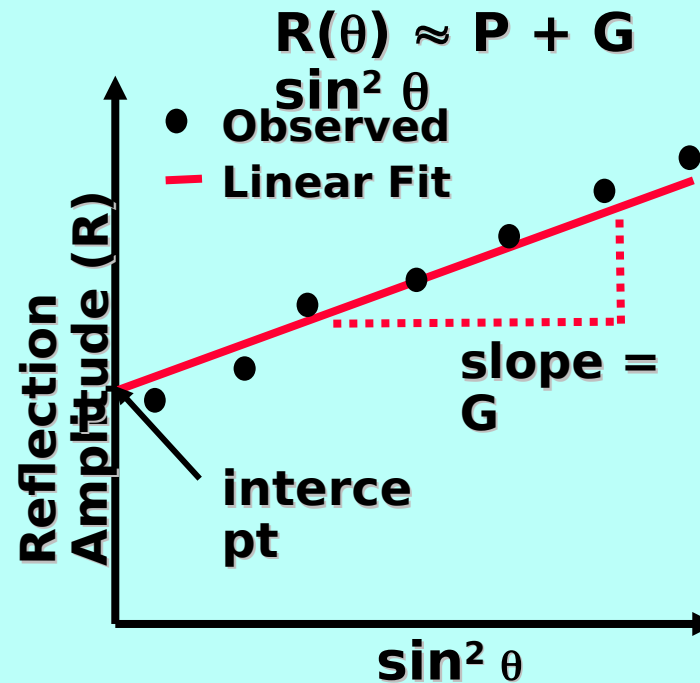
Amplitude Vs Angle

Common Angle of incidence calculated from smoothed stacking velocities



AVO Intercept and Gradient

Angle
e

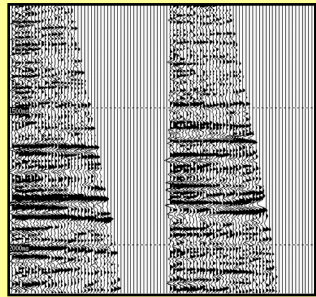


Intercept trace Gradient trace

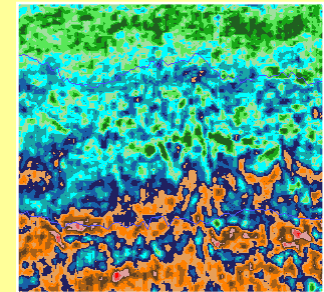
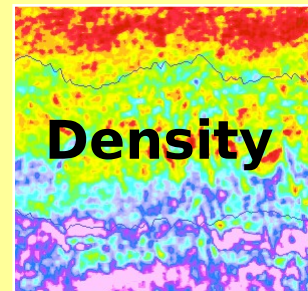
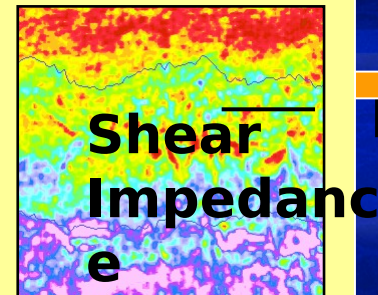
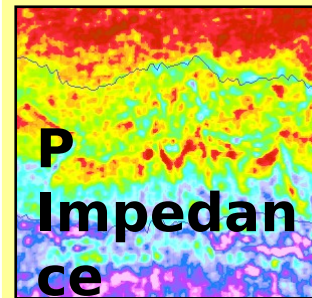
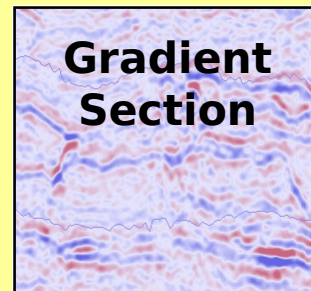
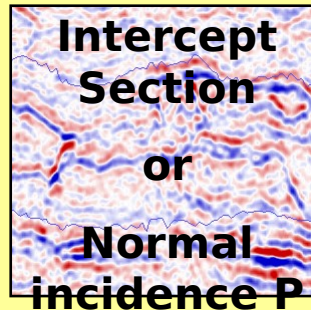
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Reservoir Properties from Seismic Data (pre-stack)

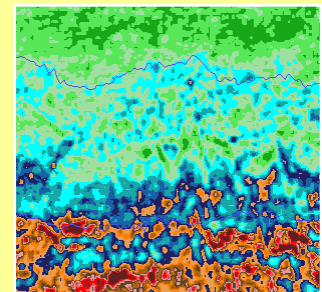
Seismic Data AVO Analysis Seismic Inversion Rock Properties



Angle Gathers

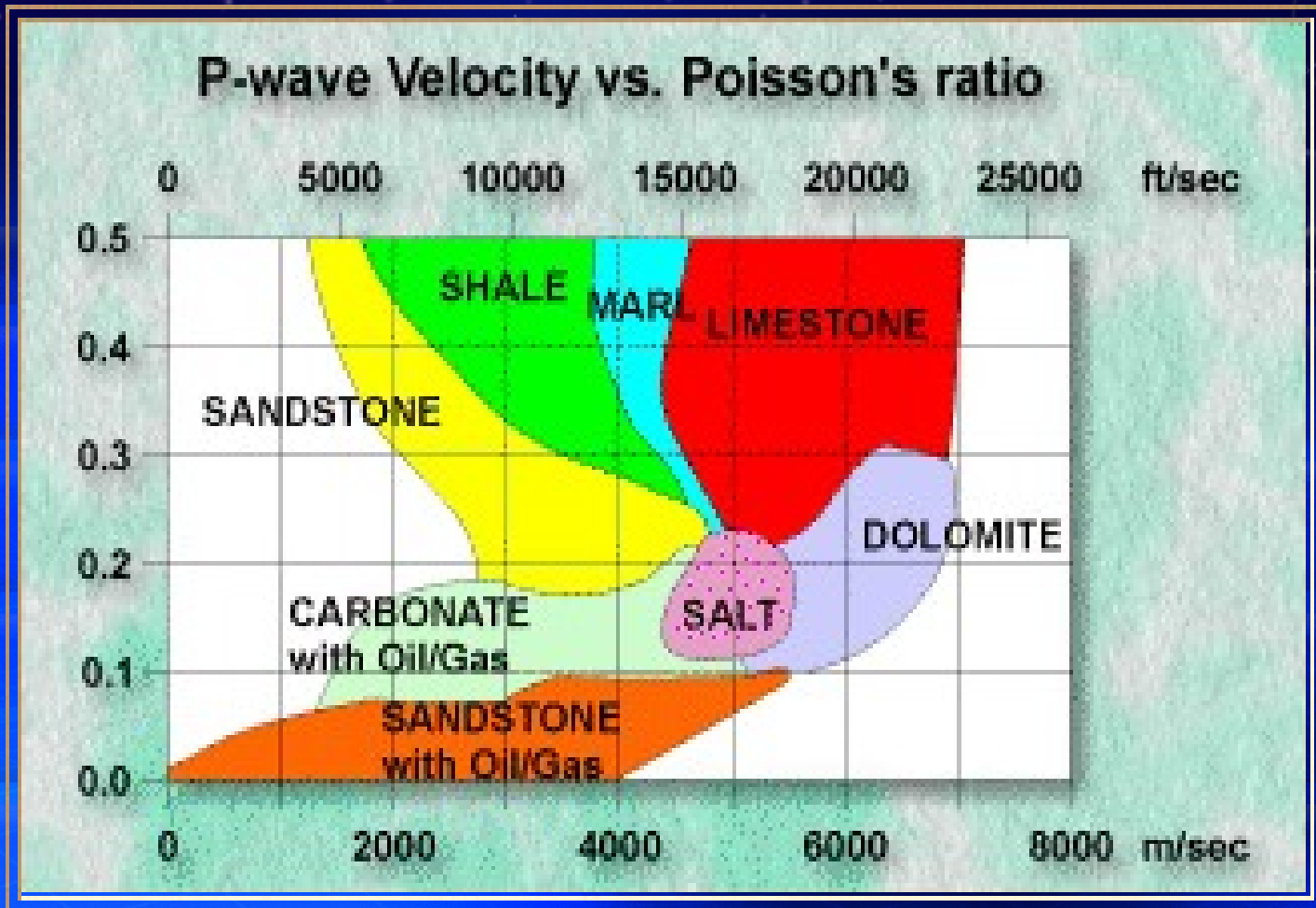


**Vp/Vs
& therefore
Poissons Ration**

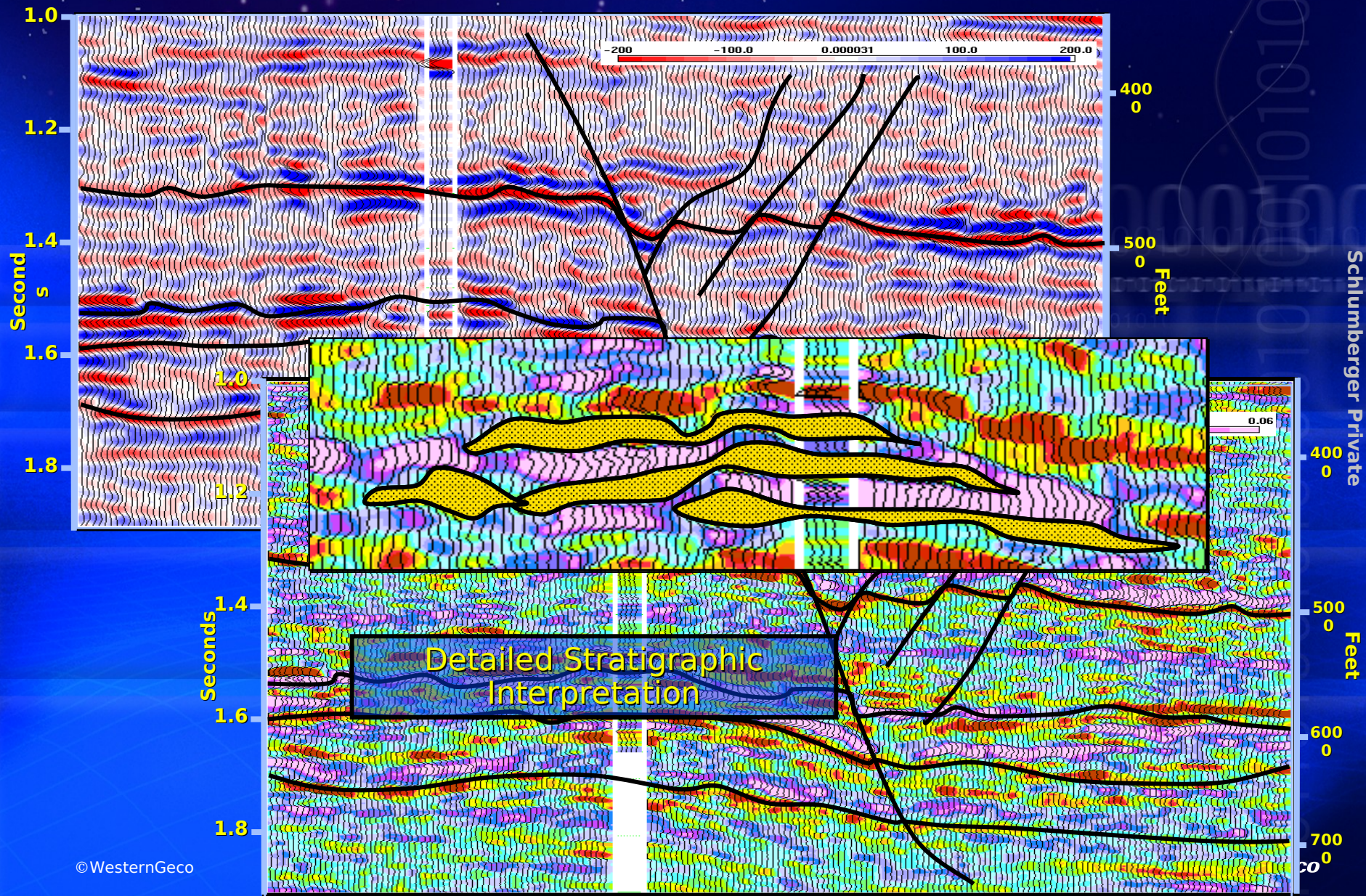


$\mu\rho$
Mu Rho

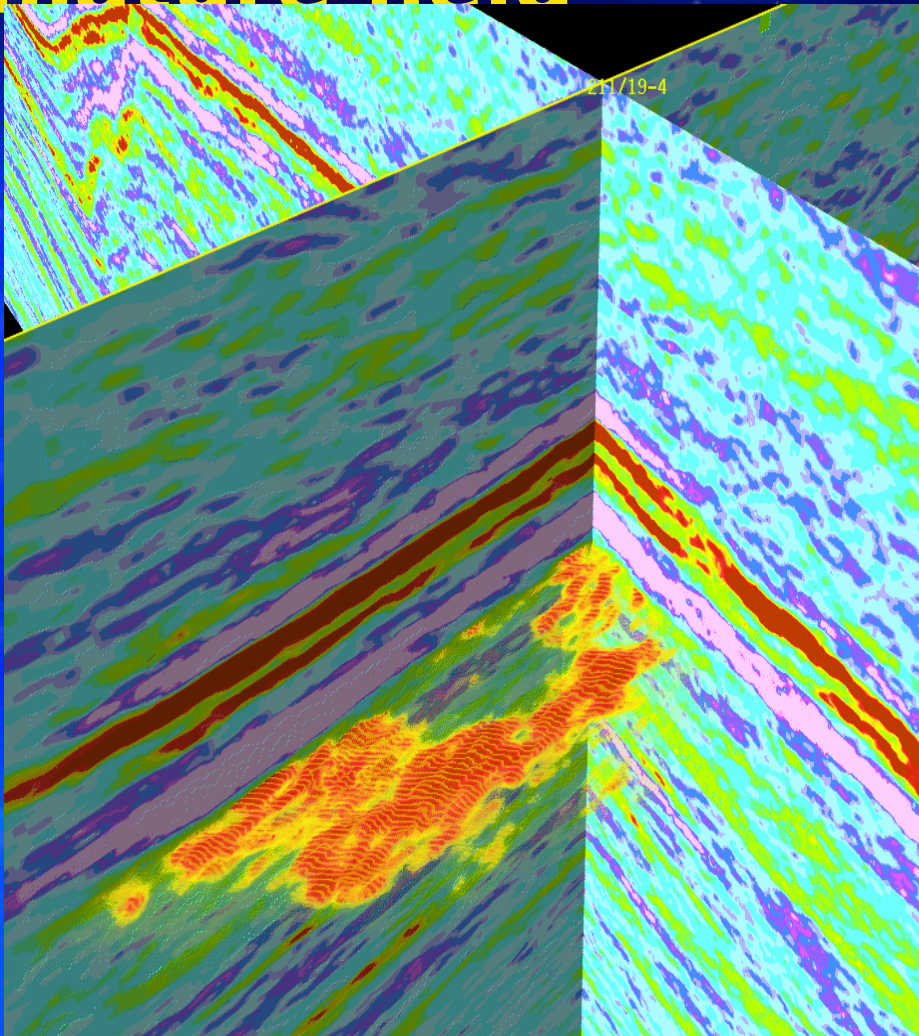
Typical P-Wave Velocities



Post-stack Acoustic Inversion

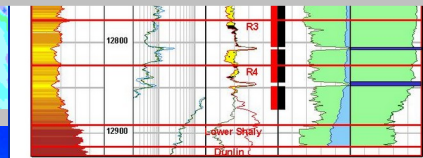


Improved seismic resolution through acoustic inversion enables resolution of thin beds in mature field

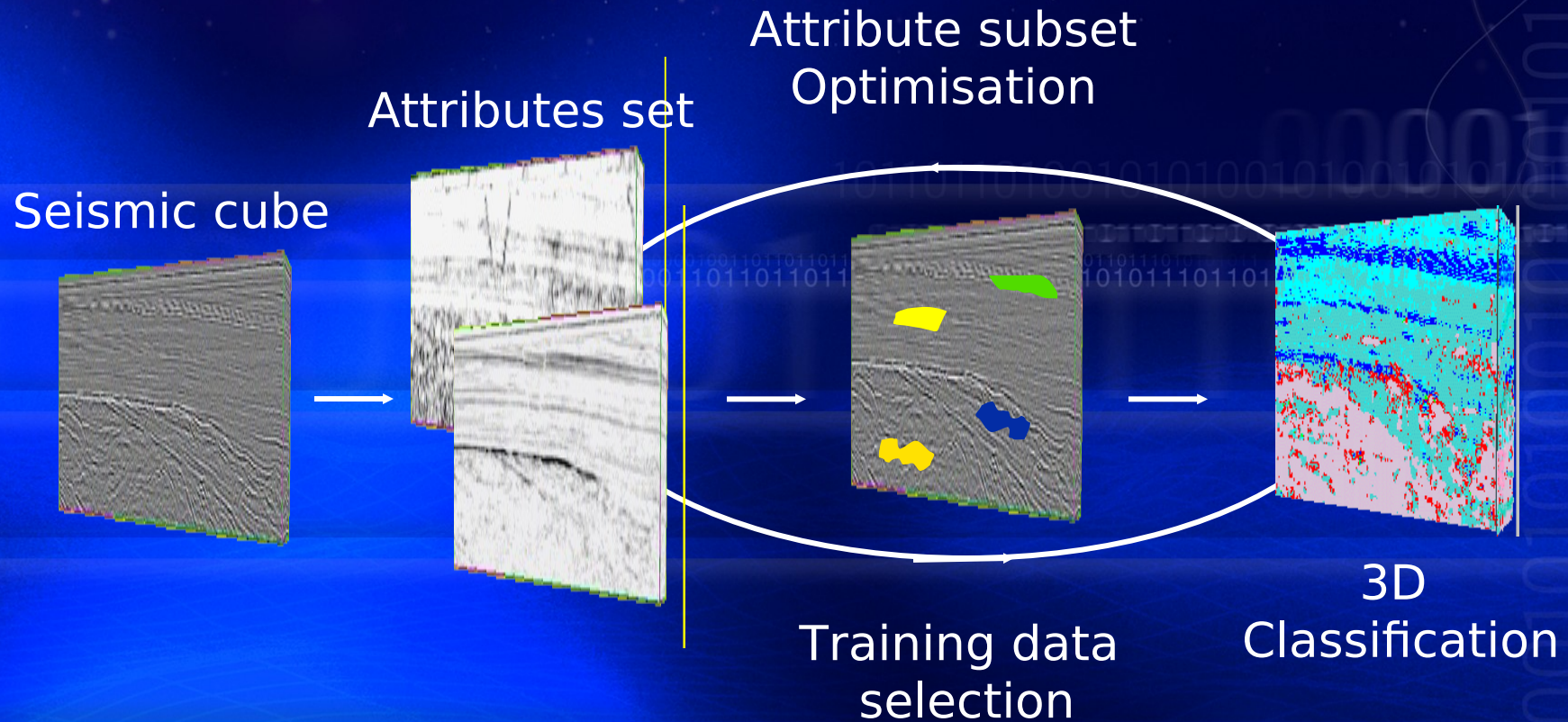


Marine seismic reveal true extent of a previously unmapped reservoir sand body in North Sea oil field. These sands from the Brent group are known to be 26 feet thick at the well location.

The definition of these sands may be instrumental in extending the life of the field



3D Seismic Classification - workflow

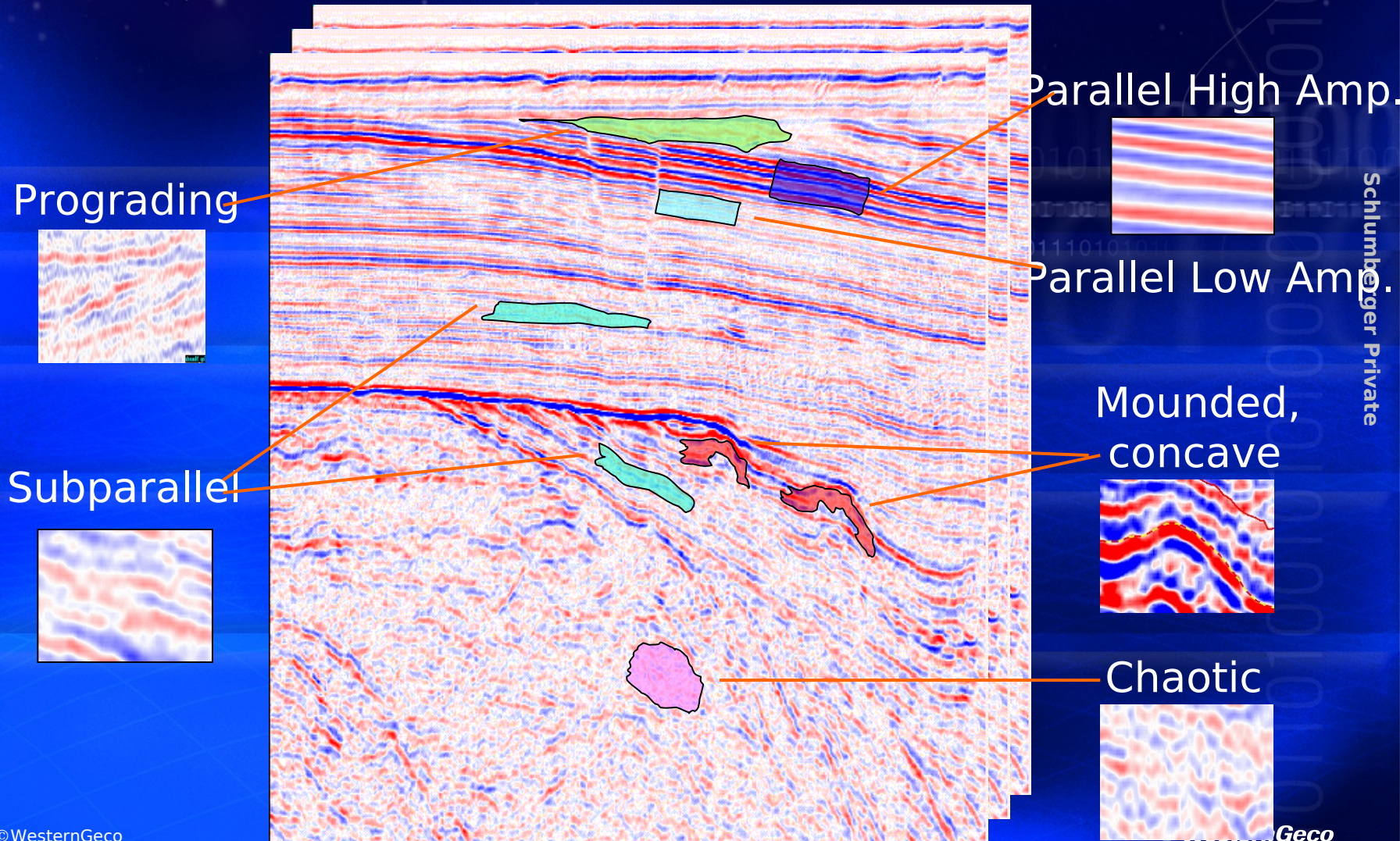


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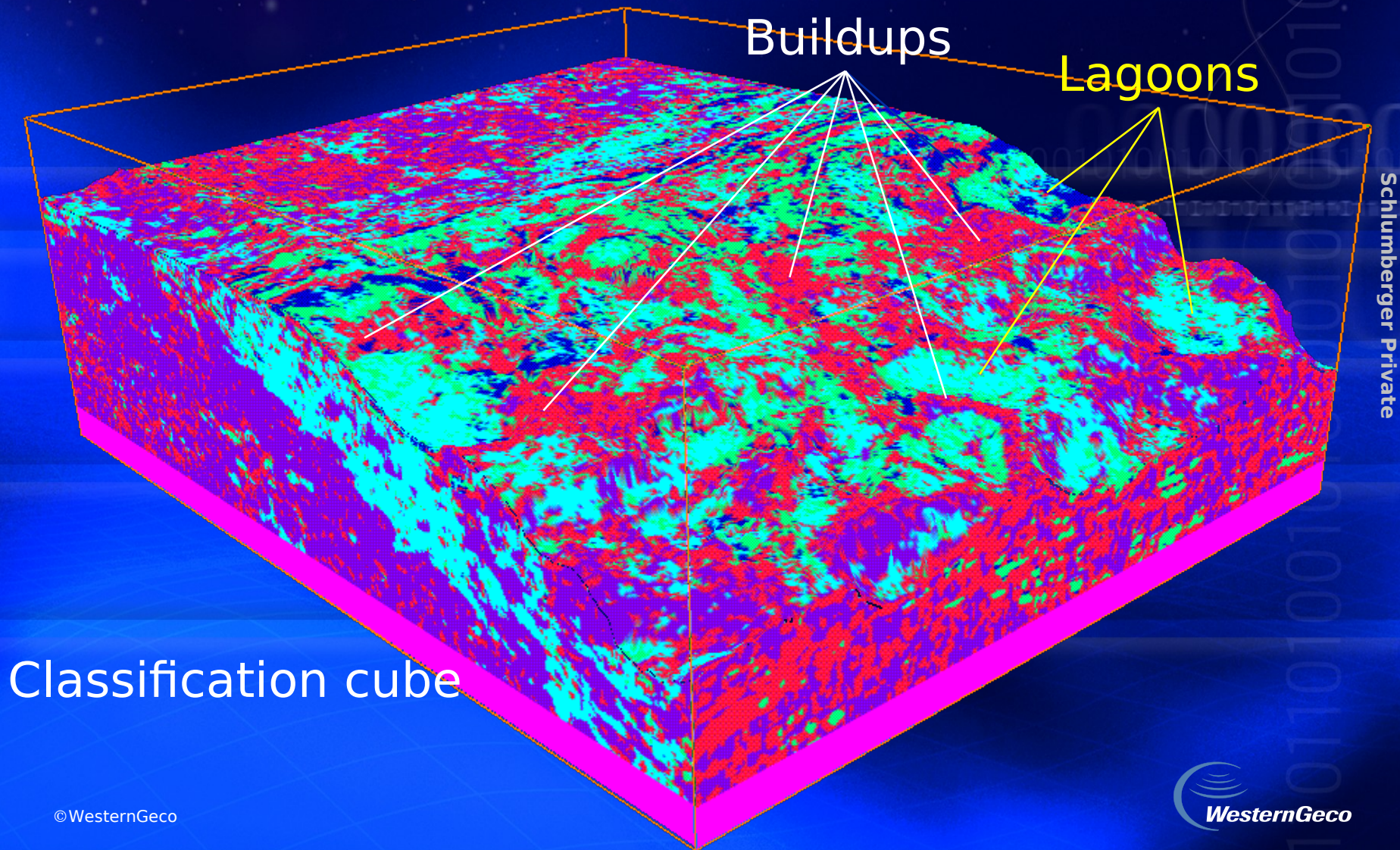
Describe the reflector-geometry in a small 3D neighbourhood

- Combination of texture attributes

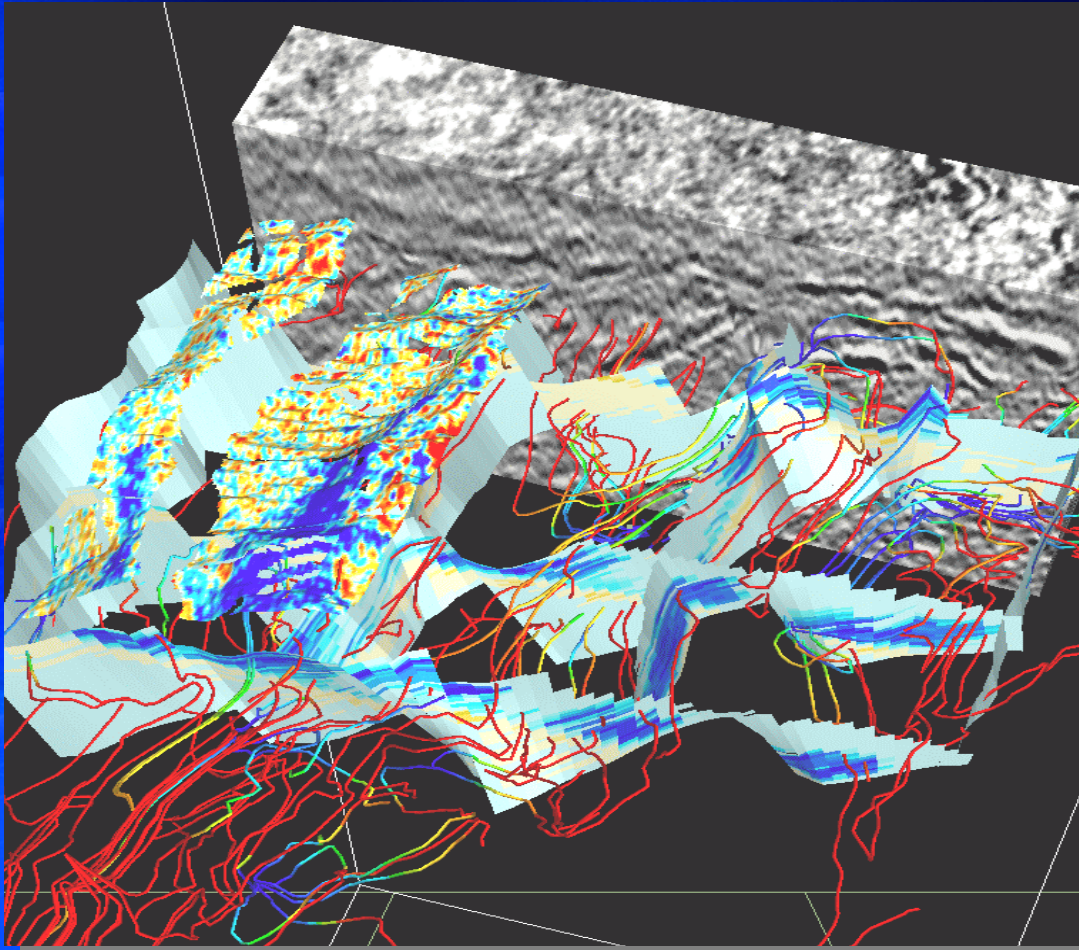
3D Seismic Classification - training data



3D Seismic Classification - results



3. Flow surveillance - monitoring reservoir saturation & pressure changes



**Reservoir
development
requirements:**

- Repeatable placement of streamers and receivers
- Less noise of all types

– Incoherent

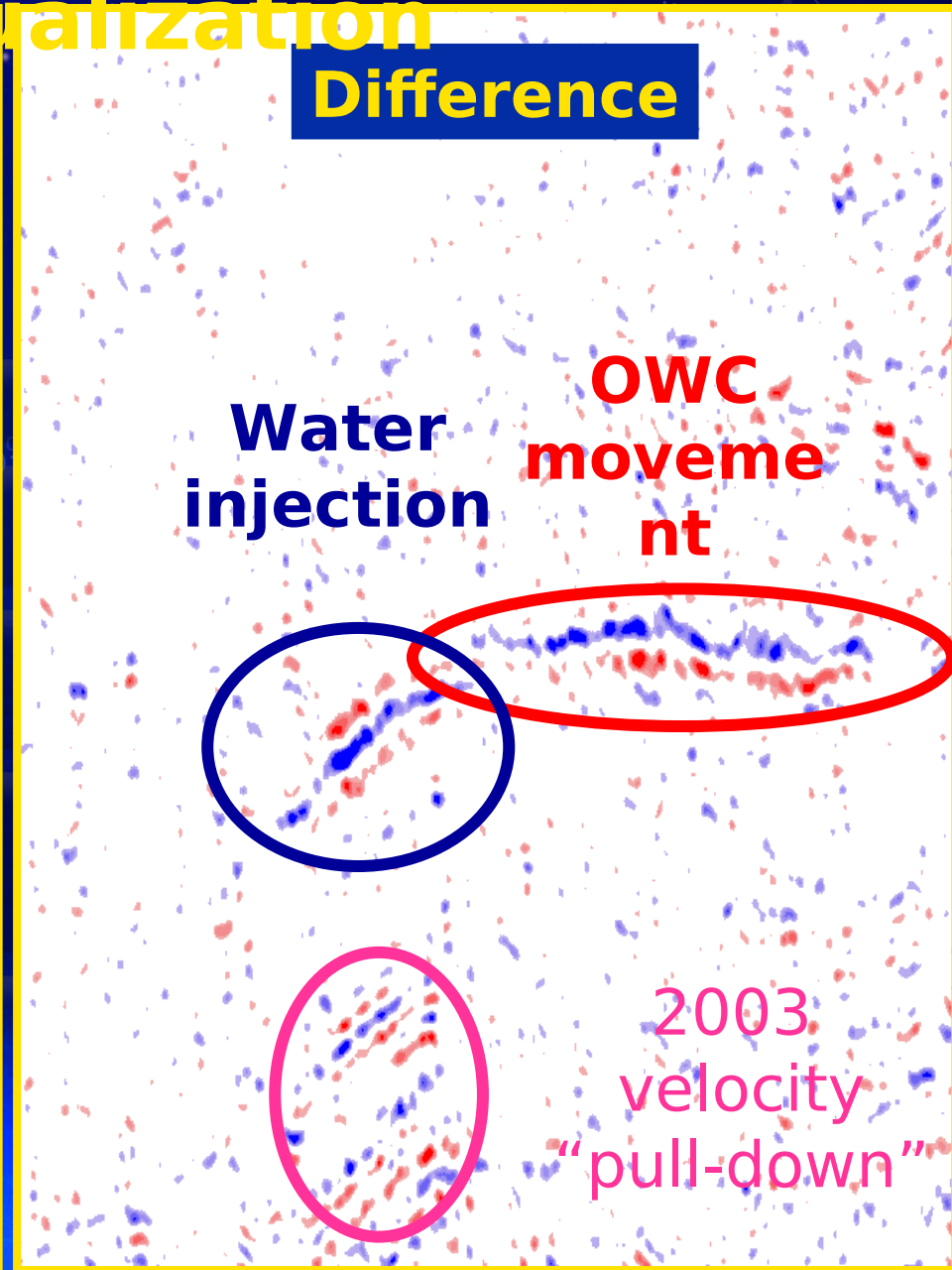
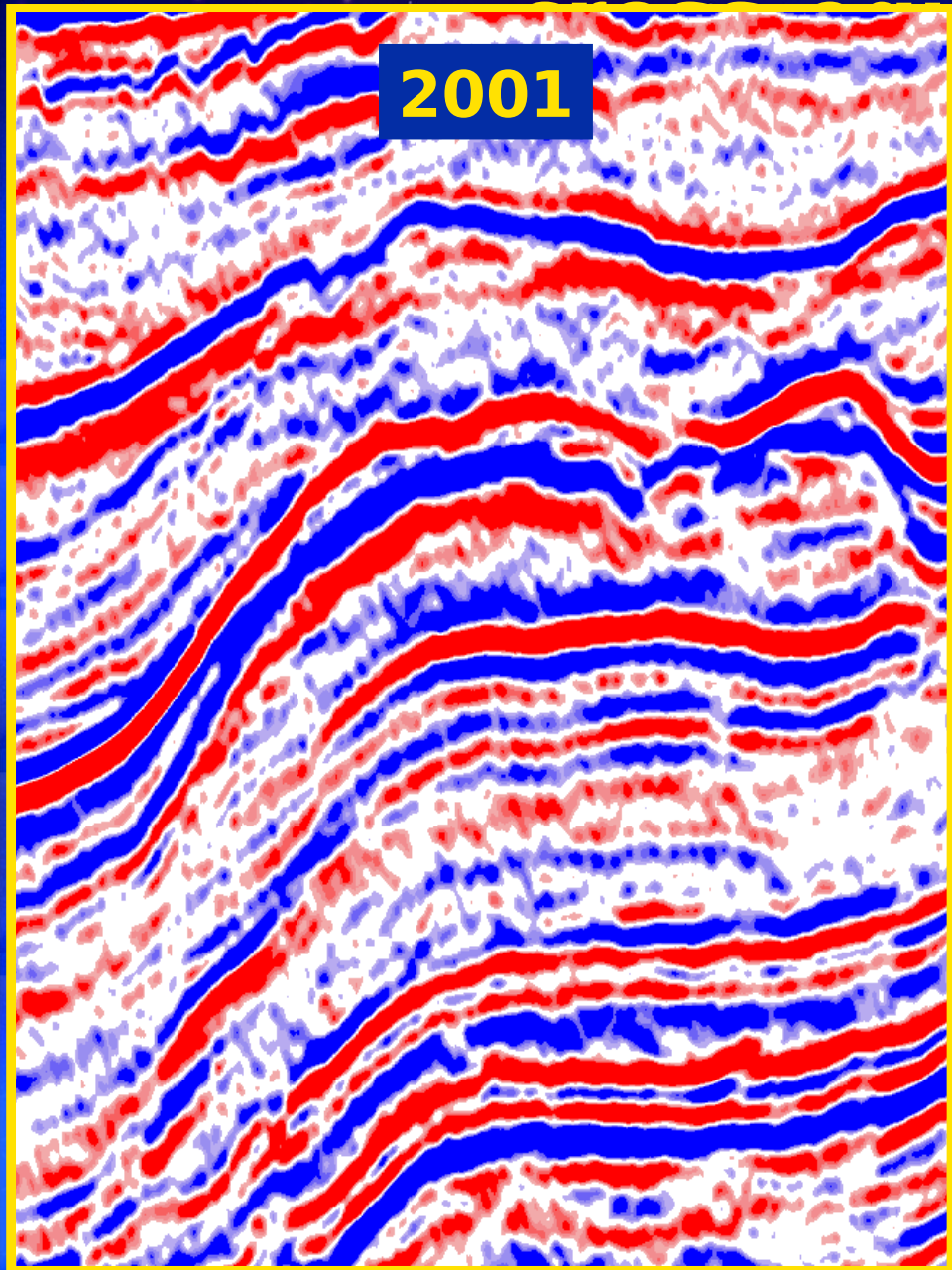
noise

– Multiples

4D Seismic - the Concept

- Also known as **Seismic Reservoir Monitoring** or **Time-Lapse Seismic**
- Consists of **3D seismic** surveys, **repeated** after intervals of substantial production
- Successive surveys analysed for **differences**
- Observes fluid **changes** in the reservoir
- Available **between & beyond the wells**

Q-on-Q 4D - true relative scaling - no normalization

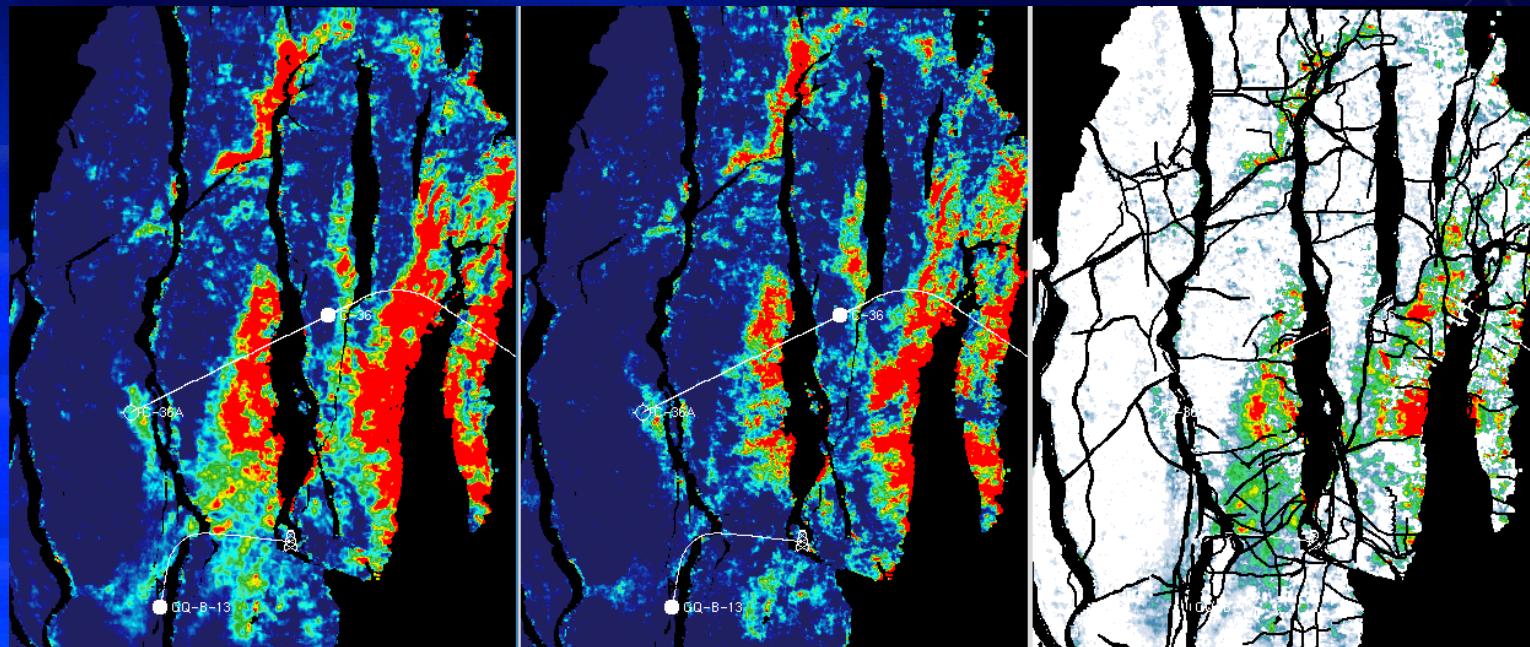


Classification of Gullfaks data

1985

1995

Difference



**34 well locations selected; additional
600 million bbl producible reserves
found as result of 4D**

An Alternative to Seismic Reservoir Description



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